METAL FIBER COMPRISING MORE THAN ONE METAL OR METAL ALLOY

Field of the invention.

The present invention relates to a metal fiber comprising several metals or metal alloys and to a method of manufacturing such a fiber.

Background of the invention.

Metal fibers are already well known in the art. The best known example is given by metal fibers obtained by bundle drawing methods.

Bundle drawn metal fibers may comprise different metal alloys, as explained in JP 5-177243.

Metal fibers obtained by coil shaving methods are known from US 4930199.

Such metal fibers may be used to provide a metal fiber media for several different applications, such as filtration of liquids or gasses, burner membranes or catalytic carriers.

Frequently the metal fiber media are to be combined with an other metal or metal alloy, in order to provide specific properties to the metal fiber medium, such as catalytic properties. Usually the metal fiber media itself is coated with another additional metal or metal alloy, which may result in an uneven distribution of the additional metal or metal alloy throughout the metal fiber medium.

Even more, it may be necessary that each metal or metal alloy is present at the outer surface of the fibers.
As described in EP0227131B1, a combination of metal can be done by blending metal fibers out of two or more types of metal fibers, each being provided out of a specific metal or metal alloy. In case a noble metal is to be present in the blended metal fiber medium, one type of

fiber may be provided out of a base metal, being coated with precious metal or metal alloy.

The use of two or more types of metal fibers, to provide combinations of metal alloys in a metal fiber media, has a disadvantage that at least two different metal fibers, out of two different metals or metal alloys are to be produced separately, after which a well mixed blend must be realized. Even in the case such well mixed blend may be obtained, there is a need for a better and more homogeneous distribution of metals in the metal fiber medium. This is especially the case if one of the metals or metal alloys comprises noble metals as a compound.

A combination of different metals or metal alloys in a wire is know from the method to provide such wires as described in GB1432906. This method has the disadvantage that it is not adapted to provide wires with cross section surfaces, which surfaces are small enough to be comparable with metal fiber dimensions.

Summary of the Invention.

The present invention has an object to provide a method to provide metal fibers comprising at least two metals or metal alloys in their cross section. The invention further has as an object to provide a method to provide metal fibers comprising at least two metals or metal alloys in their cross section, which fibers have a smaller equivalent diameter as known in the art. The invention further has as an object to provide a method for providing metal fibers which is cheap in production and which reduces the cost of making metal fiber media comprising more than one metal alloy. The invention also has as an object to provide a process of manufacturing of metal fiber and metal fiber media having an increased flexibility in combination of different metal alloys and the ratio of such different alloys. The invention also has as an object to provide a process of manufacturing of metal fiber and metal fiber media having improved

homogeneity of distribution of different metal alloys present in a metal fiber media comprising more than one metal alloy

The present invention has an object to provide a metal fiber comprising at least two different metals or metal alloys over its cross section and which has a reduced equivalent diameter. The present invention has an object to provide a metal fiber which facilitates and simplifies the process of manufacturing of metal fiber media comprising more than one metal alloy.

The present invention has further as an object to provide a metal fiber which is cheap in production and which reduces the cost of making metal fiber media comprising more than one metal alloy. This especially in case noble metals are to be used and combined.

The present invention has an object to provide a metal fiber which provide to the process of manufacturing of metal fiber media an increased flexibility in combination of different metal alloys and the ratio of such different alloys.

The present invention has an object to provide a metal fiber which improves the homogeneity of distribution of different metal alloys present in a metal fiber media comprising more than one metal alloy.

A method to produce metal fibers as subject of the invention comprises the step of:

- Providing a foil or plate which is composed of metal or metal alloy M1;
- Applying at a first side of said foil or plate a layer of a second metal or metal alloy M2;
- Coiling up said foil or plate comprising M1 and M2 on a shaft;
- Rotating said shaft with coiled foil or plate and cutting the end surface of said coiled foil or plate using a cutting tool.

A metal fiber comprising more than two metals or metal alloys as subject of the invention can made using following method.

A foil or plate out of metal or metal alloy M1 is coated on one side with a layer of metal or metal alloy M2. At the second side of the foil or plate,

being the side where no metal M2 is present, a layer of a third metal or metal alloy M3 is applied. Possibly other, successive layers of different metals may be applied, either on one or on both sides of the foil or plate. Such additional layers between M1 and M2 or M3 if applicable, may be provided to improve the anchoring between M1 and M2 or M3, or may be provided to obtain a fiber having more than 3 metals or metal elements at the outer surface of the fibers.
This foil or plate is than coiled on a shaft and subsequently the end surface of the coiled foil or plate is cut using a cutting tool.

The metal fibers obtained may have a substantially polygonal, e.g. substantially quadrangular or even substantially rectangular or even substantially square cross section.
The sides of the polygon may not be absolute straight between two angles of the polygon. The sides may also include minor protuberances or indentations or may be corrugated. This is especially the case using common industrial cutting tools.

Providing metal fibers in this way has several advantages. Applying a layer of a second metal to the foil or plate can be done fairly easily using different processes. The thickness of the layer can be varied to a large extent, which enables one to vary easily the content of M1 and M2 in the cross section of the fibers obtained. An extra advantage is that, in case M2 is composed of a precious or semi-precious metal or metal alloy, the thickness of the layer M2 can be reduced to a minimum (as an example less than 5 µm or even less than 100 Å). This enables to reduce the price of the metal fibers with such precious or semi-precious metal or metal alloy at the outer surface of the fiber. Possibly, the surface of M1 measured in a cross section of the metal fiber, is more than 90% or even more than 95% such as more than 98% of the total surface of this cross section.

The method of production of metal fibers as subject of the invention has also the advantage that the throughput time of the material is minimized, economizing the production cost.

The methods as subject of the invention may provide metal fibers having an equivalent diameter being preferably smaller than 150µm, such as smaller than 100µm or even smaller than 80µm, as an example smaller than 66µm, e.g. 65µm, 35µm or 22µm. The term "equivalent diameter" is defined as the diameter of an imaginary circle, which circle has the same surface as the surface of a cross section of the fiber in case.

A metal fiber as subject of the invention has a cross section, which cross section has a perimeter. The metal fiber is characterized in that the cross section comprises at least a first and a second zone. Each of these zones provides a part of the perimeter. The first zone is composed of a first metal or metal alloy M1, whereas the second zone is composed of a second metal or metal alloy M2, whereby M1 is different from M2. The metal fibers have an equivalent diameter being preferably smaller than 150µm, such as smaller than 100µm or even smaller than 80µm, as an example smaller than 66µm, e.g. 65µm, 35µm or 22µm.

The cross section of the metal fiber is preferably substantially polygonal, most preferred substantially quadrangular such as substantially rectangular or substantially square.

With "cross section" is meant a section of the metal fiber perpendicular to the main axis of the metal fiber.

With "substantially polygonal" is meant that the profile of the cross section has the shape of a polygonal, such as a quadrangle, a rectangle or a square, but the sides of the polygon may not be absolute straight between two angles of the polygon. The sides may also include minor protuberances or indentations or may be corrugated.

Possibly, the metal fibers as subject of the invention may comprise more than two, as an example three or even more metal or metal alloys. The method may comprise one or more additional steps of applying additional successive layers of different metals or metal alloys to one or both sides of the metal foil prior to the coiling step. Each of the metals provide a zone of the cross section. These zones provide each a part of the perimeter of the metal fibers cross section. This means that each metal or metal alloy is externally exposed. The method may comprise one or more additional steps of applying additional layers of different metals or metal alloys to one or both sides of the metal foil prior to the coiling step. The cross section of the fiber will obtain a layered outlook, each of the layers providing a zone of a specific metal or metal alloy, which provided a part of the perimeter of the cross section. In such a way, metal fibers may be obtained having more than two, such as three or more metals or metal alloys present at its outer fiber surface. For each layer or zone, the metal or metal alloy may be different, or some layers or zones may consist of the same metal or metal alloy.

Preferably M1 is composed of stainless steel, as an example out of an alloy from the AISI 400-serie, or any other Fe-Ni-Cr alloy, or Fe-Al-Cr alloy.

Possibly, M2, M3 and all additional metals or metal alloys may be chosen out of the group consisting of Cu, Ni, Pt, Pd, Ag, Au, Rh, V, W, Fe, Mo, Ir, Al, Ti, Ce or an alloy comprising at least one element out of this group. Possibly M2 and/or M3 and/or any other additional metal or metal alloy may be present as metal oxide.

It is understood that M2 and M3 may be identical or different. Also the additional layers of metal or metal alloy may be identical or different from M2 or M3.

The layers composed of M2, and if applicable M3 or any other layer of metal or metal alloy, applied to the foil or plate composed of M1, may be provided by e.g. sputtering, spraying thermal spraying, electrolytic coating or dip coating or any other known technique.

The shape of the cross section may be varied according to the cutting means used to cut of the end surface of the coiled foil or plate, according to the thickness of the coiled foil or plate and the moving speed of the cutting means, moving in the direction of the axis of the shaft.

The shape of the cross section is usually substantially rectangular. One pair of sides (hereafter called A) of the rectangle is determined by the moving speed of the cutting means in axis direction of the rotating shaft during cutting of the end surface of the coiled foil or plate. The other pair of sides (hereafter called B) of the rectangle is determined by the coiled plate or foil thickness.

The perimeter of a cross section is composed out of the sum of lengths of the sides of A and B.
The sides A correspond to surfaces with the metal or metal alloy which is present at that side of the foil or plate prior to cutting. The sides B comprise over its length several parts, each part being provided by the layers of metal or metal alloy present in several zones in the cross section.

If the thickness of the coiled foil or plate is chosen in accordance with the cutting speed of the cutting means, one may obtain a substantially square cross section.

The metal fibers, as subject of the invention, may further be processed into a fiber web. This fiber web may be used as metal fiber medium for several applications, such as filtration media or catalytic converter media or burner membrane. One of the metal or metal alloys present in the

cross section, usually, the metal or metal alloy providing the majority of surface of the cross section of the metal fiber, may provide the mechanical resistance of the metal fiber. Possibly, the other metals or metal alloys may function as a catalyst when the media is used as catalytic converter media. Another function of the other metal or metal alloy is to increase the electrical conductivity. This is the case with e.g. Cu, Al, Ag and/or Au.

Brief description of the drawings.

The invention will now be described into more detail with reference to the accompanying drawings wherein FIGURE 1, FIGURE 2, FIGURE 3 and FIGURE 4 show schematically a metal fiber as subject of the invention. FIGURE 5 shows schematically the different production steps of a process as subject of the invention for making a metal fiber.

Description of the preferred embodiments of the invention.

A cross section of a metal fiber 100 as subject of the invention is shown in FIGURE 1. The metal fiber cross section 100, which is substantially polygon, in this case quadrangular, even substantially rectangular. comprises a first zone 101 and a second zone 102. The first zone 101 is provided using a first metal M1, as an example a stainless steel alloy comprising aluminum, chromium and iron. This first zone 101 provides the sections 111, 112 and 113 of the perimeter of the metal fibers cross section. the second zone 102 provides the sections 121, 122 and 123 of the perimeter of the metal fibers cross section. As an example the metal used to provide the second zone is Pd.

As an example the metal fiber 100 of FIGURE 1 has an equivalent diameter R. This means that the surface $\pi*R^2/4$ is equal to the multiplication of the fiber first side length 133 with the sum of the layer thickness 131 and 132 of the first zone 101, respectively second zone 132. As an example, the metal fiber 100 has an equivalent diameter of

80µm, for which the fibers first side length 133 is 50µm, the thickness 131 of first zone 101 is 100µm and the thickness 132 of second zone 102 is 0.01µm. The first zone 101 provides 99.99% of the total surface of the cross section, and provides 86% of the perimeter of this cross section. It is clear that each of the metal and metal alloy providing zones 101 and 102 are externally exposed.

As an alternative, the first zone 101 is provided using a stainless steel alloy comprising aluminum, chromium and iron. The metal used to provide the second zone is Cu.
The metal fiber 100 has an equivalent diameter of 35µm, for which the fibers first side length 133 is 19.3µm, the thickness 131 of first zone 101 is 50µm and the thickness 132 of second zone 102 is 0.05µm. The first zone 101 provides 99.9% of the total surface of the cross section, and provides 86% of the perimeter of this cross section.

An other embodiment, shown in FIGURE 2, a metal fiber 200 with a cross section being substantially square, comprises a first zone 201 and a second zone 202 in its cross section. The first zone is provided using an iron-chromium-aluminum stainless steel, whereas the second zone is provided using copper. Both zones have substantially equivalent thickness 231, respectively 232 being 28.5µm. The metal fiber first side length 233 is equal to the sum of thickness 231 and 232, thus being 57µm. The resulting equivalent diameter of the metal fiber is 65µm, whereas the perimeter of the metal fiber consist for 50% out of the metal alloy of the first zone, and for 50% out of the metal of the second zone.

Yet an other embodiment of a metal fiber 300 as subject of the invention is shown in FIGURE 3. a cross section of the metal fiber shows three zones 301, 302 and 303. The first zone, consisting of an iron-chromium-aluminum stainless steel, has a thickness 331 of e.g. 100µm. At two opposite sides of the quadrangular cross section, this first zone is bound by a second or a third zone 302, respectively 33, which both have a very limited thickness 332, respectively 333 of 0.01µm each. Second zone

302 and thirds zone 303 may be provided out of Pd or Pt. The fiber first side length 334 is 50.25μm, which results in a metal fiber having an equivalent diameter of 80μm, and of which the first zone 301 provides 99.98% of the total surface of the cross section. The perimeter of the metal fiber is provided for 66.5x% out of metal from the first zone 301, and for 33.5% out of metal of the second 302 and third zone 303.

An other embodiment of a metal fiber 400 as subject of the invention is shown in FIGURE 4.
A cross section of the metal fiber comprises five zones, 401, 402, 403, 404 and 405. The first zone has a thickness 431 and is provided using a stainless steel alloy out of the AISI 400 series, such as AISI 444. At two opposite sides of the quadrangular cross section, a thin second and third zone 402 and 403 of Ti is provided, with thickness 432 and 433 These second and third zone 402 and 403 serve as a tying layer between the first zone 401 and the fourth and fifth zone 404and 405, being provided out of copper. Fourth zone 404 and fifth zone 405 have a thickness 434 and 435. it is understood that, depending on the thickness chosen, the percentages of metals in the cross sections surface may be varies largely, whereas each of the layers is externally exposed to the perimeter of the cross section.

It is understood that, according to the metals or metal alloys required in the metal fiber, other metals or metal alloys may be used.

A method to make a metal fiber being substantially polygon and having a cross section comprising two zones of different metal fibers, is shown in FIGURE 5.

In a first step 501, a foil 510 or plate out of a first metal or metal alloy M1 is provided. This foil has a thickness 560. As an example, a foil out of an iron-chromium-aluminum with thickness 100μm is provided.

In a second step 502, the foil 510 of metal or metal alloy M1, is provided with al layer 521 of a second metal or metal alloy M2, using a coating process 520, e.g. sputtering, spraying thermal spraying, electrolytic coating or dip coating. A metal foil 522 comprising M1 and M2 is obtained, having a thickness 561. As an example, the iron-chromium-aluminum alloy foil is coated with a layer of Cu having a thickness 561of 0.05μm, by sputter coating. A coated foil of thickness 100.05μm. is provided.
In a next step 503, the foil 522 comprising M1 and M2 is coiled on a shaft 530, providing a stack 531 of foil 522 on the shaft 530.
In a fourth step, the stack 531 is cut from the rotating shaft 530, rotating round its axis 541 using a cutting tool 542. This to provide a bundle 543 of metal fibers 570 as subject of the invention. The cutting tool moves in the direction of the axis of the shaft, towards the remaining stack 531 with a speed of a defined number of μm per rotation of the shaft, as indicated with 565 on FIGURE 5.

The metal fibers cross section 570, as shown in the detail 505, comprises two zones 571, out of metal M1, and a second zone 572 out of M2. The thickness of metal foil 510 correspond with the thickness of the first zone 571. The thickness of metal layer 521 correspond with the thickness of the second zone 572. The fiber first side length 563 is determined and approximates the moving speed 565 of the cutting tool.

As seen on detail 505, the sides of the metal fiber 570 are not exactly straight but include minor protuberances or indentations or may be corrugated. This is due to the cutting action and the upset during cutting.